EXECUTIVE SUMMARY

This Phase II Accreditation Support Package (ASP-II) is intended to provide users of the ESAMS model with confidence that outputs resulting from valid ranges of inputs should be reasonably valid representations of real world conditions and outcomes. It also identifies critical assumptions and limitations of the model so the user can be aware of what areas of model performance can be validly used to draw conclusions, and what areas can not. The overall objective of ASP-II activities is the identification of that set of problems for which ESAMS is expected to produce reasonable results (the application domain) as well as those functional elements (FEs) that are critical to model level measures of performance (MOPs) and are, therefore, potential targets for detailed V&V efforts. V&V activities that contribute to meeting this objective are divided into two categories:

> **Logical Verification**, which ensures that the basic equations, algorithms, and design of the model are reasonable and correct, and which identifies assumptions and limitations inherent in the implementation; and,
>
> **Face Validation**, which consists of input data verification and validation, comparison of model outputs with intelligence data and known or best estimates, and a review of sensitivity analysis results.

ASP-II documentation provides software design information in the Conceptual Model Specification (CMS) that supports *Logical Verification* and Sensitivity Analysis Reports (SARs) that support *Face Validation*. When coupled with ASP-I information, ASP-II provides the user with the best available confidence level in model results short of detailed, total model V&V, which is addressed in Phase III.

Results of logical verification include characterizations of model functionality that do not agree exactly with the known physical world. These are classified as either assumptions or limitations and are manifested in either an individual FE or in the model as a whole (have a large effect on model level MOPs). Model level assumptions and limitations and those for specific FEs are listed in Tables i-1 through i-3. These were derived from conceptual model specifications, which are equivalent to software design documents that were reverse engineered from existing code. These assumptions and limitations may impact model use to the extent that they affect certain aspects of intended applications. Detailed descriptions of their aspects and implementations are provided in the CMS section (2.0) for each FE addressed thus far.

TABLE i-1. *ESAMS* Model Level Assumptions and Limitations.

Assumptions/Limitations	Conditions of Applicability/Implications
Maximum number of Monte Carlo replications is limited to 60.	When Monte Carlo option is selected
Only one-on-one engagements. Each engagement is an independent event.	Always.
X, Y, and Z positions are accurate and error free.	Always.
Units used are seconds, meters, degrees for angle of attack and target orientation, radians for other angles, kilograms, degrees Kelvin.	Always.

TABLE i-1. *ESAMS* Model Level Assumptions and Limitations.

Assumptions/Limitations	Conditions of Applicability/Implications
Small differences may occur between results generated on different computer types.	When using different computer types. Comparisons should be made between computer types running test cases.
Digital terrain factes will in general exhibit slope discontiuities at the edges when tilted.	When digital terrain is used backscatter algorithms based on geometric reflection assumptions may periodic, strong flashes.
Maximum of 10 terrain files or 175 (40 x 40 point) squares can be used.	When digital terrain is used
Number of flight path positions is limited to 1200.	When discrete points or test data are used as inputs
Maximum number of radar sites is 200.	Always
One target (RCS) is used per flyout.	Always.
Target RCS is aspect dependent.	Always.
RCS values are symmetrical about left and right halves.	Only symetrical targets can be evaluated.
Bistatic RCS effects for seekers are approximated.	When semi-active missiles are simulated
RCS signature is a point source.	For far field. Tracking may be more accurate than for actual signatures.
Noise sources are modeled stochastically.	When enabled by the user.
Clutter model uses terrain type only, not associated tilts.	When clutter is enabled
Four-step Runge-Kutta integration with a time step chosen for the expected flight regime is sufficient to calculate successive trajectory positions.	Always. A speed-up option can be invoked to increase the time step up to eight times under certain circumstances. Arbitrary increases of computaion interval without regard to Eigen-values can produce significant modeling errors in integrated variables.
Euler integration can be used to drive the autopilots.	Always
Missile motion is simulated with a five-degrees of freedom (5-DOF) model. It is assumed that this is sufficient to simulate missile flight.	Intercept factors affected by roll angles are not addressed, and the impast of roll stabilization on intercept capability is unknown.
Missile angle of attack at intercept may be unrealistic.	Always
Commands uplinked to and downlinked from the missile are error free.	When command-guided missiles are simulated. May result in higher missile accuracy than actually achievable.
Closest point of approach (CPA) is based upon target and missile positions at fuzing, or at a simulation-ending condition.	Always
Equivalent height and width of vulnerable components are assumed for fragment Pk.	Always
Fuzing is dependent upon the specification of target glitter points and a fixed time delay.	When the advanced fuze model is not used.

TABLE i-2. *ESAMS* FE Level Assumptions.

Functional Element	Assumptions	Conditions of Applicability
Signature RCS Static	Geometric interpolation of RCS between RCS data values in a table will yield an adequately accurate representation on the target's RCS at any aspect. Nearfield RCS can be simulated using tables of RCS values.	Always When nearfield signatures are modeled.
Signature Fluctuations	Glint effects are modeled as noise that is correlated with target rotation rate. Scintillation effects will represent the four Swerling cases.	Always
ECM Off Board Deceptive	Chaff clouds are represented in a simplified geometrical model made up of a number of parcels dispensed with each parcel is subdivided into five subparcels. Parcels are approximated as rectangular shapes.	When chaff is used.
Clutter	Native Mode: A flat earth is assumed in the clutter patch area computation Depression angle from antenna to the clutter terrain patch is assumed to be the grazing angle of incidence. Radar horizon computation assumes bare, spherical earth geometry with refraction correction using the four-thirds earth radius. All terrain cells have common terrain type and surface roughness values. An empirically-derived "clutter visibility" factor accounts for the statistical likelihood of masking by intervening terrain.	When clutter is enabled
Multipath	Native Mode: Specular multipath includes returns from direct-indirect (one bounce) round-trip paths only. Multipath is not applicable to missile seekers.	When multipath calculations are enabled
Waveform Generator	The pulses in the waveform are ideally square pulses characterized simply by the carrier frequency, the PRF, and the nominal pulse-width.	For all waveform driven radars.
	Modeling the CW illumination as a pulsed waveform will yield the same seeker tracking at the effects level as modeling it as CW.	For all CW radars.
Clutter Rejection MTI	Implementation simulates a generic, idealized MTI system.	Always

TABLE i-2. *ESAMS* FE Level Assumptions.

Functional Element	Assumptions	Conditions of Applicability
Angle Tracking	Generic approach represents motor and tachometer dynamics loop with constant gain.	Always
Range Tracking	Range gate and signals are represented as rectangular pulses with center location, width, magnitude, and phase	For range error measurement.
	It is assumed the six filter types available in ESAMS should allow for a reasonable approximation of system performance.	Always
Autopilot Lateral	The missile is perfectly roll stabilized. The missile has identical symetry about the y and z body axes. The time step is small enough to approximate inpout command as a linear function over the time step interval.	Always Always. Always.
Force & Moment Generation Missile Movement	Missile is roll stabilized; i.e., rolling moment is always zero. Contribution of drag in the y & z directions is negligible, as is the contribution of lift in the x direction Atmospheric conditions are assumed to be standard day. Missile is assumed to fly without roll and be symmetrical about y and z body axes. Missile properties (thrust, mass, CG, etc.) and acceleration are constant over time step duration.	Always Always

TABLE i-3. *ESAMS* FE Level Limitations.

Functional Element	Limitations	Conditions of Applicability
Signature RCS Static	Geometric interpolation may not yield RCS values adequate for some kinds of analysis requirements Use of tables for simulationg nearfield RCS may not be adequate for all uses. Nearfiled signature data is generally not available Detailed signature data is often not available.	When table data points are far apart, particularly in LO applications. Fuzing on small sized LO targets such as missiles. Always For many existing targets, and for all developmental targets.
Target Signature Fluctuations	Glint effect equations need to be modified for maneuvering targets. Scintillation from multiple and directive reflectors not addressed.	At close ranges when target dimensions can contribute to tracking errors
ECM Noise On Board	ESAMS has no SAM "operator" modeled. Skilled opertors could be effective against noise jamming.	When an operator could affect ability of the system to track the target

TABLE i-3. *ESAMS* FE Level Limitations.

Functional Element	Limitations	Conditions of Applicability
ECM Deception On Board	ESAMS has no SAM "operator" modeled. Skilled opertors could be effective against deceptive jamming.	When an operator could affect ability of the system to track the target.
ECM Deception Off Board	No chaff rocket A human operator is not modeled. Chaff modeling may not be high enough fidelit	When forward firing chaff is the appropriate mode of chaff use. When an operator could affect ability of the system to track the target. When modeling newer SAM systems with sophisticated processing.
Clutter	Only rural/low-relief, rural/high-relief and urban terrain types are used to derive terrain reflectivity.	When clutter is enabled
Multipath	Small angle approximations are used for depression angles from the radar and target to terrain bounce points and associated grazing angles. Implementation is limited to flat-earth terrain, even though code is designed for digitized terrain. Diffraction effects are not modeled.	When multipath calculations are enabled
Waveform Generator	No operator. Waveform cannot be changed to meet changing target conditions. Radar waveform is modeled perfectly. Use of perfect square pulse shape, frequency, etc. may result in better radar performance that could actually be achieved.	When it would be appropriate to change the waveform to improve radar performance. For all waveform driven radars. Could significantly affect the results in some ECM situations and against LO targets.
MTI	Notch filter implementation is an idealized representation. Delay-line canceler implementation is a generic representation of MTI filter during pulse-by-pulse operation.	When enabled
Angle Track	The inner loop with the positioning motor and tachometer dynamics achieves a steady-state response much sooner than the outer loop.	Always
Range Track	Simplified modeling of range gate and signals limits the capability to handle pulse-shaping and taking into account any other non-rectangular features of gates and signals. Except for the one system specific filter, the filter types available in ESAMS may not allow for a reasonable approximation of system performance.	During range error measurement. Always, except for the one specific system filter available.
Force and Moment Generation	Lookup tables for lift, drag, and moment coefficients are limited by Mach number and angle-of-attack.	Always
Missile Movement	Simulation of rolling airframe missiles may be unrealistic.	Always

Sensitivity analyses performed for several functional elements (FEs) are provided in section 3. All FEs were initially examined for their relative contribution to model level measures of performance (MOPs) such as probability of kill (Pk), but many of these results were deemed inappropriate for any indications of FE level impact on model level outcomes. Conclusions drawn from the FE sensitivity analyses included here are summarized in the following paragraphs. Results of sensitivity analyses conducted on system specific radar models are currently classified SECRET/NOFORN pending review and reconciliation with the ESAMS Security Classification Guide. These documents may be obtained via requests to the SMART Project Office. Some are being revised for inclusion in the unclassified ASP and will be included at a later date.

Flight Path: Errors in flight path coordinates can be generated by the model when interpolating between positions provided for maneuvering targets. These can be minimized and rendered negligible when time intervals between data points are sufficiently small (less than 0.5 seconds).

Signature Fluctuations: Target glint is modeled as a correlated noise process that induces small errors in angle tracking, but is limited to ranges that are short enough for the target to exhibit significant physical extent and thereby distort the returned wavefront. Amplitude scintillation of target returns is simulated by random draws from two types of distributions, but contributions to tracking errors are very small and probably not significant enough to affect missile guidance.

On-board Deceptive ECM: Several countermeasure techniques including gate pulloff, terrain bounce, crosseye and wobbulation, or swept square wave jamming are available in the model and sensitivity to target Pk was examined for two of them. Results were not included due to their system-specific nature, but a generic description of their implementation is included in section 3.8.

Off-board Deceptive CM: Chaff frequency response, cloud bloom rate, and chaff speed characteristics all seem to be resonable. Chaff RCS grows initially with the size of presented chaff cloud area, but is limited to a maximum of the dipole response. This arbitrarily limits chaff effectiveness to target signatures of the same or smaller RCS as the dipole response. An MDR has been submitted.

The towed decoy sensitivity anaysis was conducted against a command guided system using repeater type jamming, but the results are expected to be similar for semi-active systems. The results show significant sensitivity to jammer J/S, tow length, and time of activation, and the trends looked reasonable.

Clutter: Even though two clutter models are available, calculations of clutter power returned from various terrain types suggest that impact on target detection and tracking would be significant only for targets with a very low (<-20 dB) RCS. Trends of calculations as a function of radar PRF and resolution length are as expected, however, and clutter power increases as altitude is reduced. The implementation is straightforward and similar to that used in other models (the user may also select the GRACE model instead of the native code), but it appears that the data used to drive the clutter reflectivity calculations might need as much examination and validation as the code itself.

Waveform Generator: Variations in both PRF jitter and pulse width can affect range tracking errors; however, even the largest errors obtained are still sufficiently small that they had no significant effect on on missile flyout performance.

Antenna Gain: Tables and functions used to represent gain patterns for radar antennas can lead to errors in off-boresight signal level calculations, which will contribute to poor tracking of targets. In cases where main beamwidth is unrealistically large, additional clutter returns will compete with those from the target. These effects will be less important for TWS radars and semi-active missiles but accurate data for antenna gain can and should be obtained and incorporated into the model.

Clutter Rejection MTI: ESAMS yields the expected MTI response as a function of Doppler frequency for 1-4 cascaded delay line cancellers.

Clutter Rejection Doppler Filters: The only potential problem with the Doppler filtering of clutter is that the Chebschev filter has an unbounded rolloff with increasing Doppler frequency. Real filters are limited to some maximum attenuation, and the ESAMS attenuation should be bounded. (An MDR has been submitted.)

Tracking Angle: ESAMS appears to be very sensitive to the characteristics of the angle tracking filters. Input data for this FE should be obtained from exploitation testing in which the filter response to ramp and step function are measured. Data collection interval should be on the order of 5% of the filter rise time for a step input.

Tracking Range: Range tracking errors in ESAMS are on the order of centimeters and are unrealistically small. This is a result of implicit assumptions such as perfectly stable PRF, perfect square-wave pulse shape, and point source target.

Changing the filter gain results in significantly different step responses. Higher gain results in larger range tracking errors, however missile flyout trajectories and miss distances were unaffected for the conditions examined.

Tracking Doppler: Doppler tracking errors in ESAMS are unrealistically small and relatively insensitive to the Doppler filter characteristics. This is largely the result of using a perfect velocity discriminator.By changing filter gain, significantly different step responses can be obtained. Higher gain results in larger Doppler trcking errors; however, missile flyout trajectories and miss distances were unaffected for the conditions examined.

Table i-4 identifies the individual Conceptual Model Specification (CMS) sections and Sensitivity Analysis Report (SAR) sections included in this version of the *ESAMS* ASP-II.

TABLE i-4. Functional Element Cross Reference Matrix.

FUNCTIONAL AREA	#	FUNCTIONAL ELEMENT	2.0 CMS	3.0 SAR
1.0 Target				
	1	1.1 Flight Path		3.1
	2	1.2.1.1 Signature RCS Static	2.2	
	3	1.2.1.2 Signature RCS Dynamic		
	4	1.2.2 Signature Fluctuations	2.4	3.4
	5	1.3.1.1 ECM Noise On-Board	2.5	
	6	1.3.1.2 ECM Noise Off-Board		
	7	1.3.1.3 ECM Noise Standoff		
	8	1.3.2.1 ECM Deception On-Board	2.8	
	9	1.3.2.2 ECM Deception Off-Board	2.9	3.9
	10	1.3.2.3 ECM Deception Standoff		
2.0 Propagation				
	11	2.1 Masking		
	12	2.2 Clutter	2.12	3.12
	13	2.3 Multipath/Diffraction	2.13	
	14	2.4 Atmospheric Attentuation		
3.0 Transmitter				
	15	3.1 Waveform Generator	2.15	3.15
4.0 Receiver				
	16	4.1 Thermal Noise		
	17	4.2 AGC		
	18	4.3 Detector		
	19	4.4 Blanking		
5.0 Antenna				
	20	5.1 Gain		3.20
	21	5.2 Scan		
6.0 Signal Processing				
	22	6.1.1 Clutter Rejection MTI	2.22	3.22
	23	6.1.2 Clutter Rejection Doppler Filters		3.23
	24	6.2 Integration		
	25	6.3 Threshold		
	26	6.4 Pulse Compression		
7.0 Target Tracking				
	27	7.1 Angle	2.27	3.27
	28	7.2 Range	2.28	3.28
	29	7.3 Doppler		3.29
8.0 Computer				
	30	8.1 Launch		
	31	8.2.1 Proportional Nav Guidance		
	32	8.2.2 Command Guidance		

TABLE i-4. Functional Element Cross Reference Matrix. (Contd.)

FUNCTIONAL AREA	#	FUNCTIONAL ELEMENT	2.0 CMS	3.0 SAR
9.0 Power Plant				
	33	9.1 Boost		
	34	9.2.1 Cruise Rocket		
	35	9.2.2 Cruise Ramjet		
10.0 Flight Control				
	36	10.1 Uplink Receiver		
	37	10.2 Beacon Transmitter		
	38	10.3.1 Autopilot Lateral	2.38	
	39	10.3.2 Autopilot Roll	2.39	
11.0 Aerodynamics				
	40	11.1 Force and Moment Generation	2.40	3.40
	41	11.2 Missile Movement	2.41	